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Research Article
Black Leaf Streak Disease Assessment During Production of Dessert Banana Basin in South-Eastern Côte D'Ivoire

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Abstract

Background and Objective: Development of a strategy to control black leaf streak disease results from the analysis of phytosanitary practices adopted in industrial plantations. This study aimed to understand the means of control implemented for managing the disease. **Materials and Methods:** In 2013, a study on black leaf streak disease management methods was carried out in the Southeastern Côte d'Ivoire. A survey in 17 industrial plantations made it possible to collect phytopathological and productivity data which were analyzed with Statistica 7.1 software. **Results:** The main results revealed that black leaf streak disease is well known and its presence has been reported in 100 p.c. of the plantations. About 44 p.c. of cases of cohabitation of black and yellow Sigatoka was reported. Integrated pest management combining leaf sanitation by removing the necrotic parts and applying synthetic fungicides is practiced in 100 p.c. of the plantations surveyed. The fungicides of the triazole, strobilurin, morpholine and benzimidazole families are used mixed in 60 p.c. and alternately in 100 p.c. of plantations. The level of disease pressure indicated by the rank of the Youngest Leaf Touched is higher in the Agneby-Tiassa region and is unevenly distributed in the production basin. **Conclusion:** The control methods for black leaf streak disease are practically identical in all the plantations surveyed except for the frequency of cutting and the stages of the disease eliminated during sanitary leaf stripping. This should be done as frequently as possible during periods of high pest pressure and concerned stages 3 or 4 of the disease.

Key words: Banana, sanitary leaf, stripping, black leaf streak disease, pest pressure

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The industrial cultivation of dessert bananas, introduced in the southern region of the Sassandra River in the late 1920s, has developed rapidly in Côte d'Ivoire and has permanently established itself in the southeast of the country[1]. Almost all banana tree plantations were located within a radius of 200 km around the city of Abidjan and its port through which exported production transits[2]. Banana production enterprises make a significant contribution to local economies in the area of employment generation; contributions to national income and Gross Domestic Product (GDP)[3]. Export production of dessert bananas estimated at 316 000 tons in 2017 positions the country as the leading African supplier of dessert bananas on the European Union market[4]. The large plantations set up for this purpose, however, face multiple constraints including fungal diseases[5], viral diseases[6], they are also threatened by bacterial wilt due to *Xanthomonas campestris* pv. *musacearum* migrating from eastern regions to western regions of Africa[7]. Among these constraints, black Sigatoka caused by *Mycosphaerella fijiensis* Morelet, is the disease most feared by farmersf[8]. The pathogen reduces plant photosynthetic capacity and crop yield[9] and also reduces fruit quality by causing premature ripening, which is a major constraint for crops grown for export[10].

In Côte d'Ivoire, this disease was detected in 1985 in the Sud-Comoé region[11] and today it is present in all banana production areas[12]. The control methods of this disease are essentially chemical and the exclusive and abusive use of this phytosanitary practice has developed foci of resistance to the families of fungicides used in certain plantations[13].

The development of an effective strategy for the control of this endemic disease in the Ivorian banana plantations will require the collection of information relating to the means of control initiated, the chemical molecules used for the treatments and the phytosanitary measures adopted in banana plantations. It is also essential to select relevant phytopathological indicators that will make it possible to analyze, to assess in order to propose effective means of control. It is within this framework that current study is interested in the analysis of the management of banana leaf diseases in the production basin of Southeastern Côte d'Ivoire. The general objective of this study was a better understanding of phytosanitary practices in progress in industrial plantations for the management of banana tree epiphyllous in general and *Mycopshaerella fijiensis* in particular. Specifically, it intends to update black Sigatoka distribution and severity map in the Southeast production basin and then analyze banana tree epiphyll control systems in order to identify the constraints to management of these pathogens.

MATERIALS AND METHOD

Area of study: The localities concerned by this study were grouped into an area corresponding to the dessert banana production basin in Côte d'Ivoire (Fig. 1). They are distributed

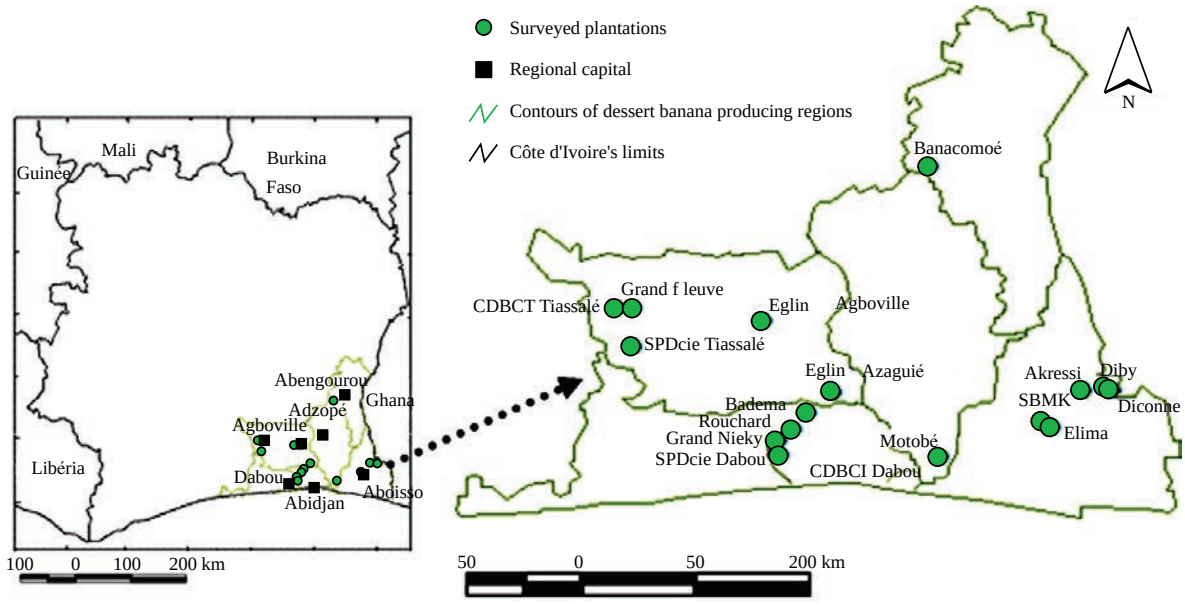

Fig. 1: Dessert industrial banana production basin in the South-East of Côte d'Ivoire

Table 1: Distribution and geographic coordinates of the dessert banana plantations surveyed

Administrative regions	Plantations surveyed	Geographic coordinates		
		Longitude (°-min-s)	Latitude (°-min-s)	Altitude (m)
Sud-Comoé	SAKJ/Akressi	003°05'31.4"	05°37'49.1"	87
	SBMK/Assouba	003°13'00.6"	05°29'14"	61
	Elima/Aboisso	003°12'39.3"	05°27'53.8"	39
	SAKJ/Diby	002°59'47"	05°39'0 2.8"	130
	SAKJ/Diconne	002°58'20.7"	05°38'0 0.8"	106
La Mé	Eglin Motobe	003°38'49.7"	05°20'0 2.9"	-8
Grands ponts	SCB Nieky	004°17'22.1"	05°24'23.5"	68
	Badema/attinguié	004°10'28.2"	05°31'57.1"	26
	Rouchard/Dabou	004°13'35"	05°27'14.5"	23
	CDBCI Dabou	004°16'33.2"	05°20'21"	6
	SPDcie Dabou	004°16'58.4"	05°20'18.9"	3
Agneby-Tiassa	Eglin Agboville	004°20'36.8"	05°56'51.2"	78
	Eglin Azaguie	004°04'26.8"	05°37'90.2"	74
	Grand fleuve	004°51'29.6"	06°00'16.7"	71
	CDBCI Broukro	004°55'16.5"	06°00'29.1"	54
	SPDcie Batia	004°51'33.5"	05°49'31.2"	46
Indenié-djuablin	Banacomoe	003°41'24.9"	06°38'21.5"	130

in five regions of the southern forest half of the country: Sud-comoé, Indénié-djuablin, Agneby-tiassa, Grands Ponts and La Mé. A total of 17 industrial plantations belonging to four agro-industrial groups (CANAVESE, EGLIN, SPDcie and SCB) were prospected. The geographic position of these plantations was determined using an ORAGELLAN 315 GPS (Table 1).

Survey and data collection: The industrial banana production basin of the Southeast covering 6000 ha[14] was surveyed from April-September, 2013. To this end, two approaches were adopted during this survey. The first consisted in assessing the level of knowledge of black leaf streak disease and other leaf fungal diseases among the stakeholders involved in dessert banana production. It consisted in going to each industrial plantation and meeting with plantation managers (plantation heads, agronomic managers, phytosanitary managers) in order to collect information on their level of knowledge concerning:

- Leaf diseases of fungal origins existing in their respective plantations
- Black Sigatoka and its damage
- Methods and means of controlling black Sigatoka
- The fungicide families, the method of use and the level of effectiveness against black Sigatoka

This information was collected on the basis of a questionnaire. The second approach consisted in going to the plots of each plantation surveyed where observations were made in the observation posts, installed in the foci of high inoculum pressure as well as in the risk areas. In the corresponding plots, 10 young (immature) banana trees, 10 flowering banana trees and 10 ready-to-harvest banana trees were selected. The observations focused on cigar deployment stage, going from 0-8, the Youngest Leaf Affected (YLA) considered as the rank of the youngest leaf carrying the first symptoms of Sigatoka, with at least 10 streaks at stage 1 of its evolution[15]. The youngest leaf bearing stage 3 of the disease (YLS3) was noted as well as the Youngest Necrotic Leaf (YLN) considered to be the youngest leaf with at least 10 necrosis at stage 6 of black Sigatoka[15,16]. The Youngest Fully Necrotic Leaf (YFNL) which is the first erect leaf with more than 80 p.c. of its necrotic surface was also taken into account. In order to assess the impact of phytosanitary treatments on banana epiphyllous fungi in industrial plantations, observations were also made in village (control) plantations located at distances between 5 and 10 km from the plots observed.

From the black Sigatoka observation sheets updated weekly by the observing agents of each plantation, the state of progress of black leaf Streak Disease (SD) was analyzed.

Mapping and data processing: Georeferencing was performed using Map Info Professional 7.5 software from a map of Côte d'Ivoire (1/1000000 scale). The projection was carried out in the WGS 84 system, zone 29, Northern hemisphere. The georeferenced map was then transferred to the Arc View Gis 3.2 software where the surveyed areas were digitized. Microsoft Office Access software made it possible to create the coordinate tables of the recorded points which, together with the Arc View Gis 3.2 software, made it possible to reveal them on the map.

Single-classification analysis of variance was used to assess the effect of *Mycosphaerella fijiensis* inoculum pressure in the areas and plantations surveyed. The averages were compared according to the Newman-Keuls test, at 5% threshold, using Statistical version 7.1 software. The maps were designed by highlighting, in the keys, disease-prevalence areas.

RESULTS

State of knowledge on banana leaf fungal diseases and black Sigatoka management means: The main diseases of banana leaves were recognized in all plantations with variable proportions depending on the leaf disease and the area surveyed (Table 2). The presence of black and yellow Sigatoka was confirmed in all plantations. Cladosporium speckle, black spot disease caused by *Deightoniella torulosa* (Syd.) M.B. Ellis and leaf spot disease caused by *Cordana musae* (Zimm.) Höhn were reported respectively in 60, 32 and 16 p.c. of plantations surveyed with a higher proportion of plantations in the Sud-Comoé region (Table 2).

Black Sigatoka was designated in 100 p.c. of plantations as the major leaf disease and its coexistence with yellow Sigatoka was reported in 44 p.c. of them (Table 2). In all plantations, the respondents presented the rainy season as the period favorable to black Sigatoka development. High relative humidity and Harmattan are also presented by 56 p.c. of the respondents as periods that can increase the severity of the disease

Chemical control (100 p.c.) and mechanical control (96 p.c.) were the two methods mainly used in banana tree plantations for the control of Sigatoka diseases (Table 3). Agronomic control is practiced in 32 p.c. of the plantations, while biological control is not practiced in any plantation (Table 3). About 96 p.c. of respondents indicated that they practice Integrated Pest Management (IPM) through a

Table 2: State of knowledge of banana tree leaf diseases in the regions surveyed

	Knowledge of banana leaf diseases (p.c.)					Presence of	Types of sigatoka (p.c.)			
Survey areas	Siga	Clado	BSD	LSD	Avg.	sigatoka in the plantation (p.c.)	Yellow	Black	Other	Periods favorable to BLSD evolution
Sud-Comoé	100	100	100	80	96	100	80	100	0	A: 100 B: 100 C: 0
La Mé	100	100	0	0	60	100	100	100	0	A: 100 B: 0 C: 100
Grands ponts	100	40	0	0	48	100	0	100	0	A: 100 B: 100 C: 100
Agneby-tiassa	100	60	60	0	64	100	40	100	0	A: 100 B: 80 C: 80
Indénié-djuablin	100	0	0	0	40	100	0	100	0	A: 100 B: 0 C: 100
Moy (p.c.)	100	60	32	16		100	44	100	0	A: 100 B: 56 C: 56

A: Rainy season, B: High relative humidity, C: Harmattan, BLSD: Black leaf streak disease, Siga: Sigatoka, Clado: Cladosporium speckle, BSD: Black spot disease, LSD: Leaf spot disease, Avg.: Average

Table 3: Black leaf streak disease control methods in the regions surveyed

	Control methods used (p.c.)					Methods for application of chemicals (p.c.)	
Survey areas	Agro	Mecha	Chem	Biol	Integrated	Syst.	Wrng
Sud-comoé	20	100	100	0	100	100	100
La Mé	0	100	100	0	100	100	100
Grands-ponts	0	80	100	0	80	40	60
Agneby-tiassa	40	100	100	0	100	80	60
Indénié-djuablin	100	100	100	0	100	100	100
Avg. (p.c.)	32	96	100	0	96	84	84

Agro: Agronomic, Mecha: Mechanical, Chem: Chemical, Biol: Biological, Syst.: Systematic, Wrng: Warning, Avg.: Average

Table 4: Chemical control of black leaf streak disease in the regions surveyed

Survey areas	Families of products used for chemical control (p.c.)				Mixture of siga control products (p.c.)	Product alternation (p.c.)	Resistance problems (p.c.)	Families of products responsible for *Mycosphaerella* sp. resistance (p.c.)				Knowledge of resistance foci (p.c.)
	Triazoles	Strobilurins	Morpholines	Benzimidazoles				Triazoles	Strobilurins	Morpholines	Benzimidazoles	
Sud-comoé	100	100	100	100	0	100	100	0	100	100	100	0
La Mé	100	100	100	100	100	100	0	0	0	0	0	0
Grands-ponts	60	40	40	40	40	100	40	40	0	0	0	20
Agneby-tiassa	100	20	100	60	80	100	60	60	0	0	0	20
Indénié-djuablin	100	100	100	100	100	100	100	100	0	0	100	100
Avg. (p.c.)	92	72	88	80	64	100	60	40	20	20	40	28

T: Triazoles, S: Strobilurins, M: Morpholines, B: Benzimidazoles, Avg.: Average, Siga: Sigatoka

Table 5: Assessment of black leaf streak disease severity in the main dessert banana producing regions

Surveyed regions	Control YNLs	YNL
Sud-comoé	5.1[c]	7.64[b]
Agneby-tiassa	5.91[bc]	9.85[a]
La Mé	3.2[d]	9.46[a]
Grands-ponts	6.36[bc]	10.92[a]
Indénié-djuablin	6.4[bc]	10.00[a]

Control YNLs: Youngest necrotic leaves in control plantations, YNL: Youngest necrotic leaves in commercial plantations, NB: The Figs followed by the same letters are not significantly different at 5 p.c. threshold (Newman keuls test)

combination of agronomic, mechanical and chemical control. Chemicals are applied systematically or on warning in 84 p.c. of plantations (Table 3).

Fungicides from the Triazoles family were used in 92 p.c. of the plantations visited (Table 4). Active ingredients such as Epoxiconazole, Difenoconazole were used by all producer groups and Methylthiophanate, Fenpropimorph by 72 p.c. mixing of products was practiced in 64 p.c. of plantations. As for product alternation, it was done in all the plantations surveyed (Table 4). However, losses in the effectiveness of the fungicides used were revealed in 60% of the plantations visited, including 100% in the Sud-comoé region where Strobulurins, Morphilines and Benzimidazoles might be the causal agents (Table 4). In the other regions, fungicides from the Triazole and Benzimidazole families were suspected of losing their effectiveness. Resistance foci were located in 28 p.c. of plantations.

***Mycosphaerella fijiensis* pest pressure and black leaf streak disease severity in the regions visited:** Table 5 shows a very significant difference in pest pressure in the control and industrial plantations in the regions visited. The Me region, with Youngest Necrotic Leaf (YNL) having an average rank equal to 3.2, was the most infested. Industrial plantations of Agneby-tiassa, La Mé, Grands-ponts and Indenié-djuablin regions ranks of youngest necrotic leaves were statistically identical. Sud-Comoe's Industrial Plantations had the lowest average ranks (7,64) of youngest necrotic leaves.

Severity measures, at a given time, the rate of destruction of the leaves of a banana tree by the disease. Figure 2 show the mapping of black streak disease severity by region and by type of plantation surveyed (industrial or control). In all regions, control plantations were the most susceptible to black streak disease (Fig. 2a). In these plantations, necrotic spots were observed on the leaves of the lower row (3.2-6.4). In the Mé region, necrotic spots were observed on leaves of rows between 1 and 3.2. In the Sud-Comoé and Agneby tiassa regions, the first necroses were observed on leaves of rows 3.3 and 5.2, respectively (Fig. 2a). Control plantations in the

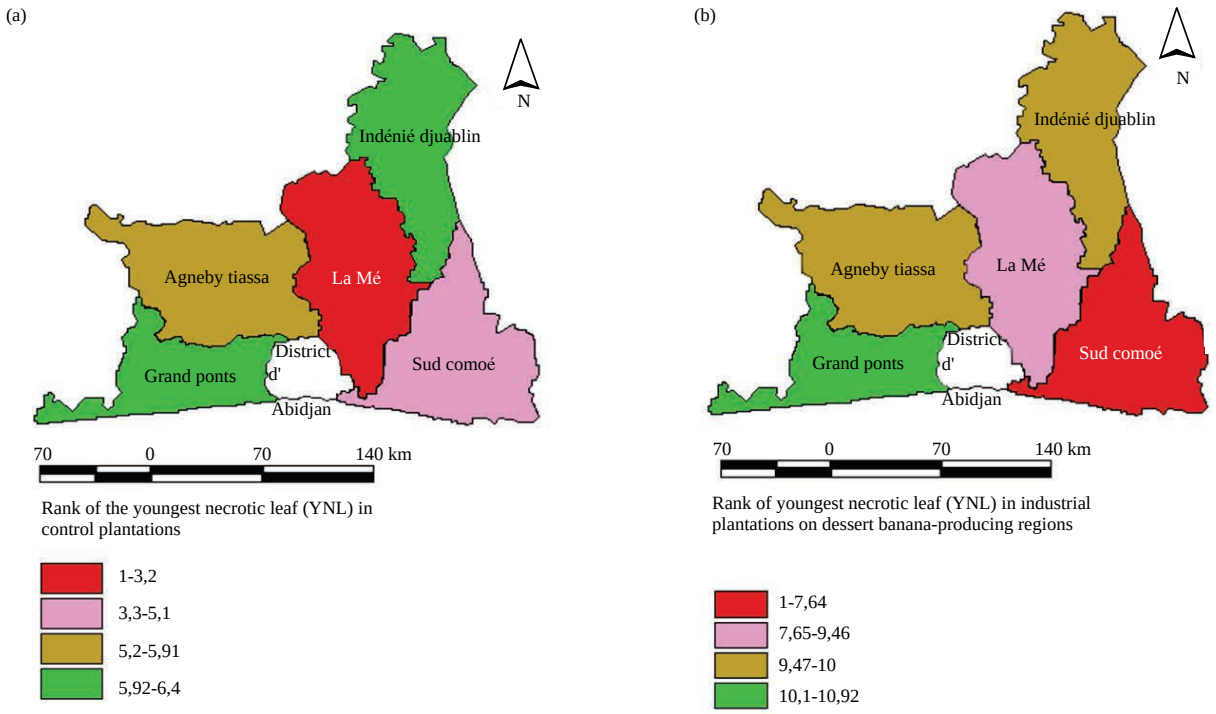

Fig. 2(a-b): Comparative illustration of black streak disease severity in the major dessert banana producing regions of Côte d'Ivoire
(a) Control plantations and (b) Industrial plantations

Table 6: Banana tree behavior vis-à-vis black leaf streak disease in the main dessert banana producing regions

	Pathological and productivity parameters			
Surveyed regions	YLA	SD	NLF	NLHa
Sud-comoé	3.79^{b}	1658.6^{a}	9.47^{bc}	2.72^{c}
Agneby-tiassa	2.63^{c}	391.7^{b}	10.91^{ab}	5.73^{b}
La Mé	3.38^{bc}	214.0^{b}	8.60^{c}	6.50^{b}
Grands-ponts	5.19^{a}	291.6^{b}	10.49^{ab}	5.45^{b}
Indénié-djuablin	3.00^{bc}	36.2^{c}	11.50^{a}	8.90^{a}

YLA: Youngest leaf affected; SD: State of evolution of the disease; NLF: Number of leaves at flowering; NLHa: Number of leaves at harvest, NB: For the same column, the Figs followed by the same letters are not significantly different at 5 p.c. threshold (Newman keuls test)

Grand-pont and Indénié-Djuablin regions were the least susceptible, with the first necrotic spots observed on leaves in row 5.92.

In industrial plantations, different levels of black streak disease severity were also observed (Fig. 2b). Necrosis was observed on leaves in rows 7.64-10.92. In the industrial plantations in the region of Grand-pont, the first necroses were observed on leaves of rows between 10.1 and 10.92. In Agneby tiassa and Indénié-Djuablin, the first necroses characteristics of black streak disease were observed on the leaves of rows 9.47-10. Plantations located in the sud-comoé region were the most susceptible to the disease with expression of necrotic disease stages on leaves of the lower rows (7.64).

The BSD's stage of development (SD) from weeks 29-34, collected during the survey phase, was very significantly different from one region to another with the strongest evolutions in the Sud-Comoé (Table 6). The level of disease recorded in Agneby Tiassa, La Mé and in Grands-ponts was statistically identical. 36.2, the lowest level of BSD progression was recorded in Indené-Djuablin.

The statistical analysis of productivity factors (NLF, NLHa) showed a significant difference between the different areas of production (Table 6). Thus, in the Indénié-Djuablin region, banana trees reached flowering with an average of 11.5 leaves, which was higher than those obtained in Grands-ponts (10.49) and Agneby-Tiassa (10.91). The lowest number of leaves at flowering was obtained in La Mé region (8.6). At harvest, 6.5, 5.73, 5.45 and 2.72 leaves were recorded respectively in La Mé, Agneby-tiassa, Grands-ponts and Sud-Comoé regions. In Indené-Djuablin, an average of 8.9 leaves were observed on banana trees ready for harvest.

Phytopathological descriptors of black leaf streak disease (YLN and SD) evaluated on banana trees in the vegetative growth phase showed statistically significant differences between the different plantations visited (Table 7). Rows of YLN ranged from 6.4-12.6. In the industrial plantations of SCB Badema and SCB Grand fleuve the first necroses were observed on leaves of row 12.6 and 12.4, respectively. At CDBCI Dabou, Rouchard and SCB Grand nieky, more than

Table 7: Banana tree behavior vis-à-vis black leaf streak disease in surveyed plantations

Surveyed plantations	Pathological and productivity parameters			
	YLN	SD	NLF	NLHa
AKRESSI	6.9^{ef}	1551.5^{b}	10.1^{cd}	2.7^{e}
SBMK	8.7^{cde}	1483.0^{b}	9.1^{de}	3.8^{de}
ELIMA	6.4^{f}	1729.8^{a}	9.6^{cd}	2.1^{e}
DIBY	7.3^{ef}	1778.5^{a}	9.0^{de}	2.7^{e}
DICONNE	8.5^{cde}	1750.3^{a}	9.3^{cde}	2.2^{e}
MOTOBE	9.5^{cd}	214.0^{f}	8.6^{de}	6.5^{b}
EGLIN Agboville	9.9^{cd}	322.5^{f}	10.0^{cd}	6.5^{b}
EGLIN Azaguié	8.0^{def}	367.5^{ef}	8.9^{de}	5.0^{bcd}
SPDcie Tiassalé	9.8^{cd}	787.2^{c}	11.8^{ab}	3.9^{de}
SPDcie Dabou	8.9^{cde}	576.3^{d}	9.1^{de}	3.1^{de}
ROUCHARD	10.7^{bc}	348.3^{ef}	7.8^{e}	4.2^{cde}
SCB Grand Niéky	10.1^{cd}	115.6^{g}	12.6^{a}	6.6^{b}
CDBCI Dabou	12.1^{ab}	126.3^{g}	12.5^{a}	8.8^{a}
SCB Grand fleuve	12.4^{a}	324.6^{ef}	11.8^{ab}	7.0^{b}
CDBCI Tiasalé	9.6^{cd}	156.4^{eg}	11.8^{ab}	6.0^{bc}
SCB Badema	12.6^{a}	130.0^{g}	10.8^{bc}	4.2^{de}
SCB Banacomoé	10.0^{cd}	36.2^{g}	11.5^{ab}	8.9^{a}

YLN: Younger necrotic leaves on commercial plantations, SD: State of evolution of the disease, NLF: Number of leaves at flowering, NLHa: Number of leaves at harvest, NB: For the same column, the Figs followed by the same letters are not significantly different at 5 p.c. threshold (Newman keuls test)

10 functional leaves at flowering were observed (Table 7). At Elima and Akressi, necrosis due to black leaf streak disease was observed on leaves of rows 6.4 and 6.9, respectively. Concerning the stage of disease development (SD), a significant effect was observed between different plantations. According to the level of the disease, plantations were classified into 8 different groups (Table 7). The first group is represented by plantations with disease stage above 1700, the second group includes Akressi and SBMK plantations. Plantations of SCB Grand-Nieky, SCB Badema, SCB Banacomoé and CDBCI Dabou with the lowest disease levels belong to the last group (Table 7).

The number of functional leaves at flowering and harvest (NLF and NLHa) showed significant differences between plantations. CDBCI Dabou had the highest number of functional leaves at both flowering and harvest (Table 7). The lowest number of functional leaves at flowering was observed at the Rouchard site (7.8) and at harvest at the sites of Elima (2.1), Diconne (2.2) and Akressi and Diby (2.7).

The high *Mycosphaerella fijiensis* pressure in Elima was confirmed with the severity of disease (6, 5) few leaves at flowering (9, 6) and lowest number of leaves at harvest (2, 1) as observed in Fig. 3a-c.

DISCUSSION

Black and yellow Sigatoka was confirmed in all plantations. Cladosporiasis due to *Cladosporium musae*, black spot disease caused by *Deightoniella torulosa* (Syd.) M.B. Ellis and leaf spot disease caused by *Cordana musae* (Zimm.) Höhn were reported in varying proportions in the plantations surveyed. The production basin located in the country's wettest zone and the frequent supply of water for the irrigation of banana plantations favour the development of fungal diseases. These results corroborate those of Koné *et al.*[17], koné *et al.*[18]. The work of Koné *et al.*[17] and those carried out in 2007[18] respectively highlighted the presence of Cladosporium speckle and the association of *Deightoniella torulosa* considered as a pest attacking plants that are weak to Sigatoka diseases, in Ivorian banana tree plantations.

In the Sud-Comoé region, a greater presence of these leaf fungal diseases was reported. Indeed, according to Essis *et al.*[12] black leaf streak disease would be more severe in this region and would promote the expression of other fungi such as *Deightoniella torulosa* which is responsible for black spots on the leaves[18]. The frequency of cuts and the stages of the disease eliminated during sanitary leaf stripping would contribute to maintaining a high inoculum pressure in the Sud Comoé region. Indeed, unlike the other areas surveyed, in this region, sanitary leaf stripping was carried out only once a week and the parts of the leaf sectioned were those which were bearing the advanced stages of the disease (5 or 6).

The presence of stages 3 and 4 on the leaves can lead in a few days to the appearance of new necrosis of stages 5-6. These stages 3 and 4 symptoms cannot be blocked by fungicide applications. Sanitary leaf stripping must be carried out as soon as stages 3 and 4 are detected, as practiced in the Indénié-Djuablin, Agneby-tiassa, La Mé and Grands ponts regions.

The work of N'guessan *et al.*[19] confirms the appropriateness of removing areas of the leaf showing stages 3 or 4 of BLSD, thus preventing the formation of reproductive structures of the fungus.

Black Sigatoka was designated in all plantations as the major leaf disease and coexists in 44 p.c. of cases with yellow Sigatoka. This predominance of black Sigatoka in Ivorian banana tree plantations was reported by Blizoua bi *et al.*[20] causing an intensification of the fight by combining mechanical and chemical control means. As for the coexistence of black and yellow Sigatoka this should be confirmed by microscopic observations of propagation organs because it is difficult to distinguish these diseases on-farm by observing only external symptoms. Under the microscope, *Mycosphaerella fijiensis* and *Mycosphaerella musicola* are mainly distinguished by the different morphological characteristics of their anamorphic stages, in particular at the level of conidiophores and conidia[21].

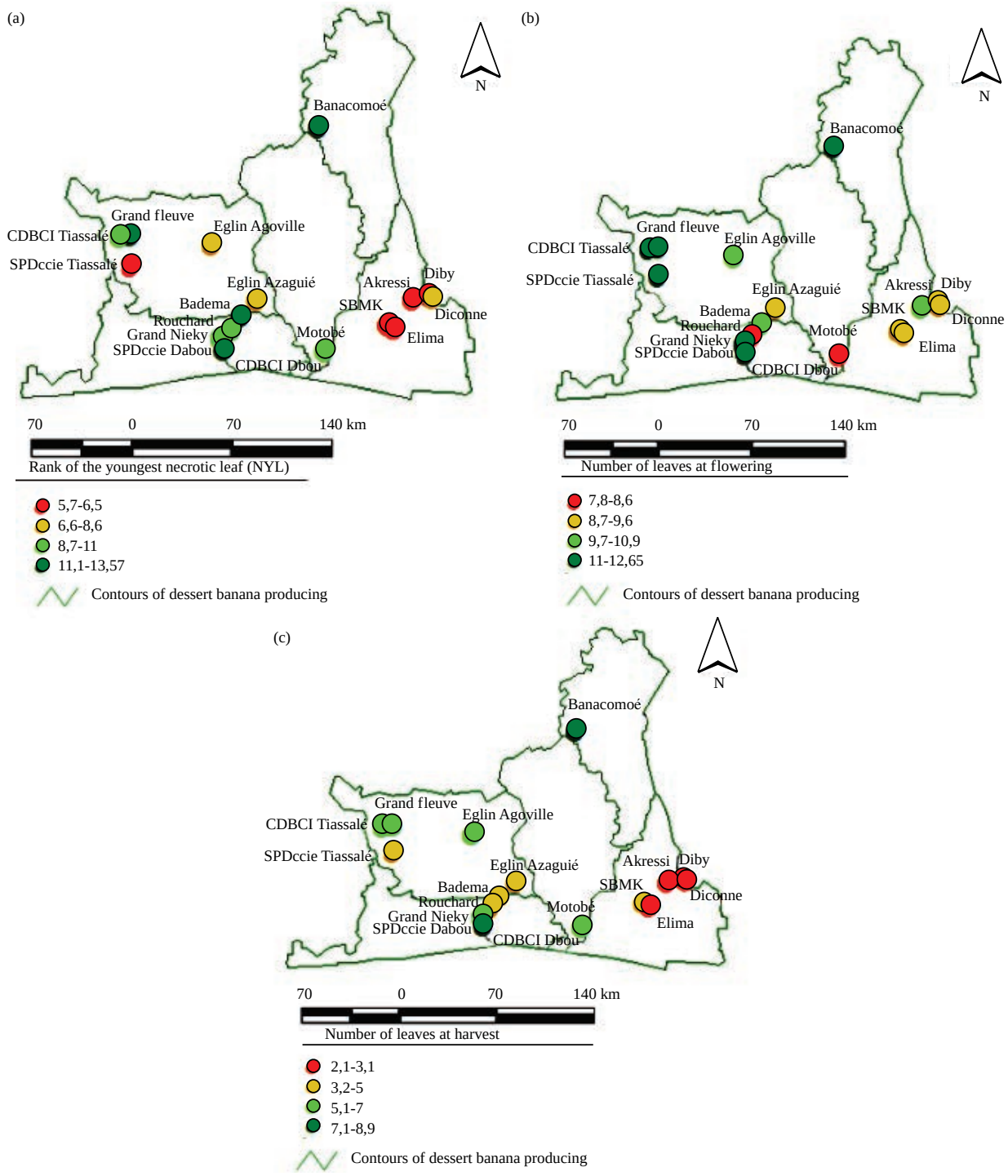

Fig. 3(a-c): Maps of *Mycosphaerella fijiensis* severity and its incidence on banana tree productivity
(a) Rank of the youngest necrotic leaf (PJFN), (b) Number of leaves at flowering (NFF) and (c) Number of leaves at harvest (NFR)

For the producers interviewed, the climatic conditions (rain, humidity, fog during the harmattan period) causing the presence of water droplets on the surface of the leaves would be favorable for the evolution of black leaf streak disease symptoms. This observation is confirmed by the work of Essis *et al.*[22] which presents the relative humidity as the main climatic factor responsible for the re-infestation of the foliage in banana tree plantations.

Integrated pest management combining leaf sanitation and applying synthetic fungicides was mainly practiced in the plantations surveyed. This management method is the one which is authorized in Martinique and Guadeloupe with applications of fungicides exclusively by land due to the problems of excess, pollution and dangerousness of aerial treatments[23].

Product application was carried out at a regular rate, most often using contact fungicides of different families (chloronitriles, dithiocarbamate, etc.) and systemic ones (triazoles, strobilurins) at intervals of ten to fifteen days, in emulsion in water or mineral oil.

These synthetic fungicides were used as a mixture in 64 p.c. of the plantations surveyed. According to Vawdrey[24], control of black leaf streak disease was more effective when the plant activator acibenzolar was used in a mixture with Mancozeb. The alternation of active ingredients during successive treatments was practiced in 100 p.c. of plantations. They thus complied with the FRAC[25] (Fungicide Resistance Action Committee) recommendations of June 2012 in order to minimize the risk of developing resistance. However, losses of effectiveness of fungicides belonging to the families of strobilurins, benzimidazoles and triazoles have been reported in the banana tree plantations visited, thus corroborating the results of Essis[26] who detected the presence of *Mycosphaerella fijiensis* strains in loss of sensitivity vis-à-vis these fungicides in Ivorian banana tree plantations.

Cladosporium musae[17,27,28] and *Deightoniella torulosa*[27] were identified among other pests in banana phyllosphere. *Deightoniella torulosa* would be considered to be a pest attacking weak plants found on the leaves and flowers of certain banana cultivars[29].

The predominance of these fungal diseases in village plantations (controls) could be explained by the effectiveness of the fungicides used against *Mycosphaerella fijiensis* on the pathogens responsible for these diseases. This hypothesis is confirmed by the work of Koné *et al.*[30] which highlighted the great sensitivity of *Cladosporium musae* and *Deigthoniella torulosa* to 4 fungicides belonging to the triazoles and strobilurins, used for *Mycosphaerella fijiensis* control.

The severity of black leaf streak disease showed a significant difference between control plantations and commercial plantations and varied from region to region. It was increasing from the Indénié-djuablin region to that of Sud-comoé where the Elima plantation showed the highest severity. Plantations in the region also showed the lowest productivity data (NLF and NLHa). This high pressure of the disease could be linked on the one hand to the presence of strains resistant to fungicide treatments and on the other hand to the climatic conditions of the area which would be favorable to the development of black leaf streak disease. The work of Essis *et al.*[26] has shown the emergence of resistance to triazoles in the areas of Aboisso, Dabou and Azaguié.

CONCLUSION

This study on the current situation of black Sigatoka in bananas in the production basin of southeastern Côte d'Ivoire has made it possible to analyze the control systems for black leaf streak disease and to update the severity map. The BLSD control methods were practically identical in all the plantations surveyed with the exception of the frequency of cuts and the stages of the disease eliminated during sanitary leaf stripping. This should be done as frequently as possible during periods of high pest pressure and should concern stages 3 or 4 of the disease; pest pressure expressed by the rank of the Youngest Leaf Affected (YLA) is unevenly distributed in the production basin and black leaf streak disease is more damaging in the Sud Comoé region.

SIGNIFICANCE STATEMENT

This study discovers management of black Sigatoka disease made it possible to analyze the control systems for black leaf streak disease and to update the severity map of this disease in the production basin of southeastern Côte d'Ivoire. That can be beneficial for the banana producer. This study will help the researchers to uncover the critical areas of banana tree folial pathology that many researchers were not able to explore. Thus a new theory on the global management of banana parasites may be arrived at.

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